Senior Project

H.F. Hauff Pruner

Power System

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## Contents

Introduction: .................................................................................................................. 4
  Motivation .................................................................................................................. 4
  Function Statement .................................................................................................. 4
  Requirements ........................................................................................................... 4
  Engineering Merit .................................................................................................... 5
  Scope of Effort ......................................................................................................... 6
  Success Criteria ....................................................................................................... 6

Design and Analysis .................................................................................................... 6
  Approach: Proposed Solution .................................................................................... 6
  Design Description ................................................................................................... 7
  Benchmark ............................................................................................................... 7
  Performance Predictions ......................................................................................... 8
  Description of Analyses ........................................................................................... 8
  Scope of Testing and Evaluation .............................................................................. 9
  Analysis .................................................................................................................... 9
  Approach: Proposed Sequence ............................................................................... 11
  Device Shape: ......................................................................................................... 11
  Device Assembly, Attachments .............................................................................. 11
  Tolerances, Kinematic, Ergonomic, etc. .................................................................. 11
  Technical Risk Analysis, Failure Mode Analyses, Safety Factors, Operation Limits .... 12

Methods and Construction ........................................................................................ 12
  Construction ............................................................................................................ 12
  Description ................................................................................................................ 12
  Drawing Tree, Drawing ID’s .................................................................................... 13
  Parts list and labels .................................................................................................. 13
  Manufacturing issues ............................................................................................... 13

Testing Method .......................................................................................................... 14
  Introduction ............................................................................................................. 14
  Method/Approach .................................................................................................... 14
  Testing Procedures .................................................................................................. 14
  Deliverables: ............................................................................................................ 15

Budget/Schedule/Project Management ....................................................................... 15
  Proposed Budget ..................................................................................................... 15
Introduction:

Motivation
Founded in 1947, H.F. Hauff Company Inc. of Yakima, Washington has been a nation-wide manufacturer and distributor of specialized agricultural equipment. The company is constantly striving to provide quality, dependable products using innovative technological advancements and the highest engineering standards. The company’s president, Neil Hauff, is the driver behind this innovation. Neil’s efforts towards perfection and customer satisfaction are the motivation behind this project.

Neil Hauff was approached by a Greek organic orchardist, Emmanuel Maniadakis. Emmanuel approached Neil with his Treelion D45-900 battery-powered pruner and he explained the issues he has with the current design.

After operating for a long time, the linear actuator which provides cutting force becomes too hot for the operator to hold the housing surrounding the actuator, even when wearing gloves. The current reach of the pruner is also not sufficient. The single-finger trigger is difficult to operate when wearing gloves and causes discomfort on the operator’s finger after pruning for a long time. Emmanuel would prefer a 4 finger trigger (hand trigger) similar to the triggers found on pneumatic tools. With the current pruner, a cut is made by holding down the trigger until a cut is made and then letting go of the trigger. Emmanuel needs a cut to be made by only pressing the trigger once, momentarily.

The new design will eliminate the heat issue with the current pruner actuator and housing. The new design will also have a longer reach. The single-finger trigger system will be replaced with a new trigger system that is more comfortable for the operator and easier to operate with gloves. For the new design, a cut will be made by pressing the trigger once, momentarily. However, Emmanuel is satisfied with the current power supply system, a 44 V DC battery belt.

Function Statement
Function statement #1 applies to the new pruner design in its entirety. Function statement #2 applies to the Power system of the new pruner design.

1. H.F. Hauff Pruner (Entire Pruner):
   - A device is needed which can cut branches all day without overheating.

2. H.F. Hauff Pruner: Power System:
   - A device is needed that transmits cutting force to the pruner blade, when initiated by the operator.

Requirements
The bulleted list below contains the design requirements for the Hauff Pruner in its entirety.

- The distance from the trigger to the end of the pruner blade must be no shorter than 36”
- After operating at a pruning rate of 250 1” diameter branches/hour for 6 hours, all the pruner components must remain under 110°F.
- The pruner must be able to cut at least a 1.5” diameter branch.
- The trigger system must be a four-finger hand trigger. (as per customer)
• The power supply must be a 44V DC battery belt. (as per customer)
• The combined weight of the pruner must be no greater than 15 lbs.
• The pruner center of mass must be within the first quarter of total pruner length (starting from handle end)
• The total cost to manufacture the pruner can be no greater than $2,500.
• The cut cycle time of each pruner cut can be no longer than 2s. (as per customer)
• At any point on the pruner, the width can be no greater than 6 in.
• The cutting cycle must be initiated by a single, momentary pull of the trigger, performed by the operator. (as per customer)
• The pruner must be manufactured within a 9 week period.

The bulleted list below contains the design requirements for the Hauff Pruner power system.

• The power system must use a 44 V DC power supply (as per customer)
• The power system must be able to supply a force to the pruner blade which can cut at minimum a 1.5” diameter branch.
• The weight of all power system components must be no greater than 7 lbs.
• The power system components must be able to fit inside 2” inner-diameter housing.
• At least 50% of the power system components’ weight must be positioned directly over the trigger system for ergonomic balance.
• When the power system is operating at a pruning rate of 250-1” diameter branches/ hour, the components must not exceed a temperature of 110 degrees F.
• The pruner power system must provide at least 450 lbs. of force to the pruner blade.
• The cutting power system must supply cutting force for 6 hours when pruning at a rate of 300 1” diameter branches/ hour.
• After a cut is initiated by the operator, the cut cycle must be no longer than 2.0 seconds. (as per customer)
• The cut cycle must be initiated by a single, momentary pull of the trigger. (as per customer)
• The trigger must be designed so 4 fingers are used to operate it. (Hand trigger) (as per customer)
• The cost of all power system components must be no greater than $800.

Engineering Merit

It is most important that the new pruner design is ergonomic. This is going to be achieved through overall weight, balance (weight kept near the handle), and a re-designed trigger system. However, the new design must also adhere to the design requirements regarding power capability, operating temperature, and reach of the pruner. A formula that will be used to find a better cutting force mechanism is the equation for duty cycle rating, D.C. = (Tc / To) *100, where Tc = Time of cycle and To = time in between cycles. Finding the required duty cycle rating for the cutting force mechanism will help ensure the new power system doesn’t overheat during operation.
Engineering merit is also present in the use of Stress equations: \( \sigma = \text{Force/Area} \). These calculations for average shear and tensile stress in the power system components help establish dimensions and material which are optimal. Material selection must be appropriate for each component in order to meet requirements and to keep cost down. Engineering merit can also be found in the material.

**Scope of Effort**
The main focus for the design of the Hauff pruner power system is its ability to provide necessary cutting force, cut cycle time, and consecutive cuts while maintaining a low operating temperature. The scope of effort also extends to the trigger system which must be a 4 finger hand trigger for ergonomic purposes.

**Success Criteria**
The success of the pruner power system depends on its ability to; remain below 110 degrees F when operating at a pruning rate of 250 1”-diameter branches/hour and provide sufficient cutting force to the blade to cut a 1.5” diameter branch at minimum. However the success criteria of the pruner power system can also be defined by the following equation which incorporates all sections of the pruner design.

\[
\text{Success Level} = \frac{(t)(T)(P)(36 \text{ in. Length})}{1.5 \text{ in. Branch Diameter}}
\]

“t” represents the time in seconds it takes for the pruner to complete one cut cycle. “T” represents the temperature of the housing surrounding the actuator/motor system after the maximum branch cut, 1.50 in. or the temperature of the housing after the pruner has cut 250 1 in. diameter branches in one hour. The 36 in. length refers to the required length from the trigger to the end of the blade. “P” refers to the maximum load required to cut a branch. The equation incorporates design requirements. If P is greater than 600 lb., T is greater than 110°F, or t is greater than 2.0 seconds, the success level will exceed a level of 146 s-°F-lb. Once this value has been exceeded, the pruner is not considered successful.

**Design and Analysis**

**Approach: Proposed Solution**
As stated before, the main problem with the power system of the current pruner is the operating temperature. The linear actuator and housing surrounding the linear actuator become too hot for the operator’s hands. To fix this problem, the new pruner design must have a linear actuator which will not exceed a temperature of 110 degrees F when operating at a rate of 250 1” diameter branches/hour for 6 hours. The selection of a more appropriate linear actuator is crucial to the success of the new design.

In order for the cutting cycle to be initiated by a single push of the trigger, electrical switches must be positioned inside the housing to open the circuit and reverse the motion of the actuator. (See Figure 2-2)
Design Description

**Figure 2-1** (Also found in Appendix A1) below displays the basic components of the pruner power system in a conceptual sketch. The power supply is the 44 V battery belt. The linear actuator transmits cutting force to the blade through the linear motion of the driving rod. The linear actuator will retract to close the blade and move forward to open it. The cutting motion is initiated by the hand trigger. The circuitry required for the cutting cycle (i.e. limit switches) is not displayed in this sketch.

**Figure 2-1: Power System Concept Sketch**

The cutting cycle must be initiated by a single pull of the hand trigger. The blade of the pruner is open when the actuator is fully forward. When the actuator is at this position, the power circuit is open due to a switch. The single push of the hand trigger will close this circuit and retract the actuator, closing the blade. When actuator reaches the end of the retraction stroke, the polarity must be switched which will send the actuator back in a forward motion until the circuit is opened again. **Appendix, A2** displays a conceptual sketch of the circuit switches.

In order for cutting cycle to be initiated with a single, momentary pull of the trigger, the circuit shown in **Figure 2-3** (Also found in Appendix, A3) must be used. This circuit includes a N.C. (Normally Closed) switch, the trigger momentary switch, and a latching 3.P.D.T. (3 pole, double throw) switch. In the final design, a safety switch will also be included to ensure the cutting action can’t be initiated by accident. And finally, the trigger circuit will also need a function to back out of a cut.

**Benchmark**

The benchmark for the design of the pruner power system is the current power system found in Emmanuel’s Treelion D45-900 electric pruner. **Figure 2-4** shows a picture of the Treelion pruner. This pruner is manufactured by Pellenc, a French agricultural company, and it costs $1950 USD. **Figure 2-5** shows the linear actuator and linkage to driving rod found in the D45-900. The actuator is also manufactured, in-house, by Pellenc (Model #: 69068-E).

**Figure 2-4: Treelion D45-900 Pruner**
This is a very valuable benchmark for the design process because the customer was mostly satisfied with the Treelion’s performance, aside from a few factors; overheating, ergonomics, and reach. Each member of the design team will use this benchmark as a guide for designing the optimized Hauff pruner.

**Performance Predictions**

The linear actuator of the new pruner design will have an average surface temperature of 70 degrees F after pruning 250 1”-diameter branches in one hour. After going at this rate for six hours, the average surface temperature of the actuator will be 75 degrees. The actuator will be able to dissipate heat at a rate appropriate for the operation demands.

A single cut cycle will be sufficient to cut a 1.5” diameter branch. The pruner blade won’t have to be backed out of the cut.

At a rate of 250 1”-diameter branches/hour, the new pruner power system will provide cutting force to the blades for 6 hours.

**Description of Analyses**

First, an analysis will be performed to determine the appropriate duty cycle rating for the new design’s linear actuator. Selecting an actuator with a suitable duty cycle rating is important because this will ensure that the new pruner design will not overheat when under the expected operating conditions. The duty cycle rating is a required specification for the selection of a more appropriate actuator. *Appendix A-5* shows the calculation for the duty cycle rating of the linear actuator.

Then, an analysis will be performed to determine the maximum linear force that is required from the actuator. The moment at which the most linear force is required for cutting a 1.5” diameter branch will be analyzed statically. The static analysis will take into account the geometry and angles in the blade linkage and blade. From this, the maximum linear force needed will be determined. This is a design parameter for the selection of a more appropriate actuator.
After the maximum required linear force is determined and an appropriate actuator is selected, an analysis on the actuator will be performed. This analysis is to determine the maximum current that will be present in the circuit when the actuator is delivering force to the blade during the 1.5” diameter branch cut. This is a design parameter for the selection of circuit components.

Scope of Testing and Evaluation
In order to test the new pruner design, a location with fruit trees must be used. During the pruner testing, a thermocouple must be used to observe the temperature of the pruner housing and linear actuator. During this testing phase, it must also be observed how efficient the cutting cycle is, with regard to battery life.

Analysis
Listed below are the different methods of analysis which are used to design the optimized pruner.

Tree Branch Testing: Round 1
To establish how much force is needed to cut various sizes of branches and where, during the cut, the most force is required, a test was performed using the Tinius Olsen tensile tester. Appendix A6 shows the testing device assembly that was manufactured for the first round of testing. Appendix A7 shows the force vs. distance of travel through the branch. The main problem with this test was the simulated cutting action. The blade was brought directly down on the branch by the tensile tester, resulting in more crushing than cutting. This also resulted in a very high maximum cutting force, about 4,000 lb. (Appendix A7). In order to more accurately simulate the shearing action of the pruner blade/anvil better, a guillotine style cutting action will have to be utilized.

Tree Branch Testing: Round 2
The second round of testing resulted in a much more accurate value for required cutting force. Appendix A8 shows a picture of the apparatus used for the second round of testing. The blade and anvil were taken from a pair of 32-inch Fiskars bypass loppers. The blade and anvil used on Fiskars were highly praised by the customer for their effectiveness. Therefore, the Fiskars blade and anvil geometry have been adopted into our design. The test data determined the force that was required at the end of the 2.50 inch moment arm, 500 lb., to cut a 1.50 inch branch. The test data for the Testing: Round 2 is found in Appendix A9.

Blade Orientation during Cut:
The geometry of the blade/anvil in Testing: Round 2 is known. Also, it is known how fast the Tinius Olsen tensile test was moving downward, 4.5 in/s. This linear, downward velocity was then converted to (in/s), 0.075 in/s. It is determined from the test data that, during the cut of 1.50 inch-diameter Cherry branch, that the maximum cutting force was needed when the Tinius Olsen had moved 1.8 inches from the start of the cut. The calculation in Appendix A10 shows how it was determined that the maximum force during this cut was needed 24 seconds into the cut. After this value was determined, the video footage of the 1.50 in Cherry branch cut was reviewed. After 24 seconds into the test cut, the video was paused and the blade orientation during maximum required cutting force was documented. (See Appendix A10)

Average Cutting Point Force:
After the Fiskars blade/anvil orientation during maximum required force on a 1.50 inch diameter branch was determined, the approximate cutting point of the blade could be located from the visual analysis of the blade/anvil orientation. From this visual analysis, it was determined that the average cutting point on the Fiskars blade during maximum required force was 1.50 inches away from the pivoting cutting joint. Also the distance from the applied force to the cutting joint was observed to be 2.3125 inches. Now that the perpendicular distances were known, it could be determined that the reaction of the branch on the blade during this maximum force moment is 770.83 lb. (See Appendix A11)

**Duty Cycle:**
Establishing an appropriate duty cycle for the cutting force device is a helpful and practical parameter for selecting a more appropriate linear actuator for power delivery to the pruner blade. (If that is the best option for the cutting force device) Appendix A5 shows a calculation which establishes a duty cycle value for the pruner cutting force device. It is assumed that the time between cutting cycles would be an average of 8 seconds. Therefore, if a linear actuator is to be used, it must have a duty cycle rating of 20% or greater.

**Mechanical Power Output:**
Even though a required linear force is not yet determined, the method that is used to find the required mechanical power output is shown on Appendix A6. If the required linear force is assumed to be 450 lbs., then the required power output is determined to be 50.9 Watts.

**Clevis Pin Sizing:**
Appendix A12 shows the analysis that was performed in order to determine the minimum diameter of the clevis pin which is to be used to transfer force from the linkages to actuator connection. From the analysis, it is determined that minimum diameter the AISI 1020 pin should be to withstand maximum cutting force is 0.152 inches. Therefore, the pins that will be used in the assembly are ¼” in diameter.

**Sizing the Carbon Fiber Driving Rod for Tensile Strength:**
Appendix A13 shows the calculation which determines the required wall thickness of the aluminum or carbon fiber tube which will be used as the driving rod in the assembly. From the calculation, it is determined that the wall thickness of a carbon fiber tube must be at least 0.0073 inches to withstand the cutting tensile force, 600 lbs. It is also determined that an aluminum tube must have a wall thickness of 0.1495 inches in order to withstand the tensile force.

**Sizing the Width of the Driving Rod Linkage Width:**
Appendix A16 shows the calculation that was done to determine the required width for the driving rod linkage (Drawing #12, Appendix B12). The thickness of the linkage 0.138” is a fixed dimensions to ensure the driving rod assembly still fits inside the housing. The size of the pin holes in the linkage are also fixed because it was determined that 0.25” was an appropriate diameter of the power system clevis pins. (See calculation in Appendix A12). It is determined that the width of the driving rod linkage must be at least 0.738” when made out of SAE 1020 Cold-drawn steel. Therefore, the final design width dimension of the linkage is ¾”.

**Driving Rod Buckling Analysis:**
Appendix A17 show the calculation which determines that the dimensions established for the driving rod in tension (calculation in Appendix A13) still give the driving rod a buckling load of 2,461 lb. This value is much higher than the rod would ever experience with maximum
compressive load it receives from the actuator. Therefore, the rod would not buckle if the blade were to become stuck and could not open.

**Approach: Proposed Sequence**
The numbered list below explains the proposed sequence of analyses for pruner power system.

1. The Tinius Olsen tensile tester will be used to determine the maximum force required during the cut of a 1.5” diameter branch. This test will also establish the point of the cut where the most force is required.
2. After the force required at the branch is determined, the department responsible for manufacturing the blades (Daniel Gibson) will perform a static analysis of the blade geometry during this point of the cut. From the analysis, it will be determined how much linear force is needed from the actuator.
3. After the required maximum linear force is established, this value and other parameters will be used to select a more appropriate actuator. The other specifications which will be considered are; stroke length, linear stroke velocity, amperage and power draw, duty cycle rating (See **Appendix A4**), maximum push/pull force, power supply voltage, and geometric dimensions.
4. After the appropriate actuator is selected, appropriate circuit components will also be selected which can handle the amperage of actuator operation.
5. Finally, the driving rod material will selected with the following specifications in mind; weight, material tensile strength (cutting action puts driving rod in tension

**Device Shape:**
The customer, Emmanuel Maniadakis, requested that the trigger system be a hand trigger. He wants to the trigger for the pruner design to be similar to the triggers found on pneumatic hand tools. He has also requested that the pruner be at least 3 feet long (from trigger to blade end).

**Device Assembly, Attachments**
The Makita XDT08 has been chosen as the most appropriate impact driver motor for the team’s application and here’s why:

- The brushless DC motor offers unparalleled efficiency and low maintenance in comparison to other brushed DC motors.
- The XDT08 is capable of producing 1420 in\(^\#\)lb of torque under normal operation. This is sufficient for the team’s application
- The XDT08 is capable at running at 2500 RPM under normal operation. This is a sufficient rotational speed in order to achieve the desired cycle time.
- The XDT08 weighs only 2 pounds. This is an ideal weight for the motor system.

**Tolerances, Kinematic, Ergonomic, etc.**
All components of the optimized pruner power system, excluding the purchased actuator, contain tolerances on all dimensions. In compliance with A.N.S.I. Y14.5-2009 drawing standards, a documented Solidworks drawing of each power system component has been constructed (See **Appendix B**). In these drawings, dimensions containing decimal values with 2 decimal places have a tolerance of ±0.030 inches. Drawing dimensions containing decimal values with 3 decimal places have a tolerance of ±0.005 inches. Tolerance stacking is a potential issue.
regarding the dimensions of the driving rod linkage and the connecting pins. Stacked tolerances for these components could cause the actuator shaft to become misaligned with the driving rod when it is rigidly housed.

The linear actuator for the optimized design produces a linear force, resulting in motion. Therefore, the kinematics of the actuator shaft motion must be discussed. In order to reach the optimal cycle time, the actuator must have linear velocity of 0.75 in/s during operation. The actuator retracts when providing cutting force. During the retraction, the actuator experiences the highest force in tension. When the actuator extends and returns the blade to the open position, the actuator is pulling, causing the power system components to be in compression.

Ergonomics is one of the most important factors for the pruner design. In order to comply with ergonomic standards for the design, multiple features are included. The trigger system must be a four-finger hand trigger to decrease the strain that a single-finger trigger places on the index finger of the operator. Also, the center of mass must be considered in the construction to reduce operator strain. One the design requirements for the entire pruner is to keep the center of mass within the first quarter of the total pruner length.

**Technical Risk Analysis, Failure Mode Analyses, Safety Factors, Operation Limits**

The optimized pruner power system design uses a safety factor of 2 for establishing the diameter of the pins used to transmit power. The calculation in Appendix A12 shows how this safety factor was used to establish this design parameter. The required pin diameter for safe power transmission in the pruner has been established to be ¼”.

**Methods and Construction**

**Construction**

The power system of the pruner will now be entirely manufactured and assembled in the Hogue machine shop. The ball screw must be modified for the application. The ball nut guide will be a rapid prototype part. The hex adapter will be turned, drilled, and bored on the lathe. The aluminum thrust plates which surround the needle thrust bearing will be laser-cut in the Hogue facilities. The aluminum plate which screw to the ball nut will be manufacture with the Bridgeport milling machine. The driving rod is now welded to the aluminum plate on the ball nut. And finally, the aluminum pin which connects to the blade linkage will be first manufactured using the lathe and the milling machine.

**Description**

The most recent design of the pruner power system is made up of a Makita Impact Driver (Model #: XDT08) (See Appendix B5), an hex adapter (See Appendix A9) which adapts the hex drive system at the end of the Makita into a torque transmitter for a ball lead screw (See Appendix A6). The ball screw drives a ball nut (See Appendix A10) forwards and backwards in a linear motion in the ball nut guide (See Appendix A14). An aluminum weld plate (See Appendix A11) is now attached to the ball nut through tapped holes added through the ball nut modification process. This weld plate is attached to the ball nut through fasteners to enable the aluminum driving rod (See Appendix A12) to be welded to the top of the ball nut assembly. The
linkage pin connector (See Appendix A13) has an interference-adhesive fit with opposite end of the driving rod which is used to connect to the linkage of the cutting system. In order to keep thrust forces away from the motor and place them in the central housing tube, a thrust bearing (See Appendix A8) and two aluminum thrust plates (See Appendix A7) are press fit into the central housing tube to capture the thrust load created by the ball screw.

**Drawing Tree, Drawing ID’s**

Appendix B15 displays the Drawing tree of the Hauff Pruner Components. All components which lead with the letter “A” in their drawing designation are components pertaining to the Power system of the pruner design.

**Parts list and labels**

Appendix C1 contains the parts list for the Hauff pruner components. Included in the parts list is quantity and price of each pruner component which will have to be purchased. The parts which are required to be purchased are a ball screw and ball nut from McMaster-Carr. Aluminum round stock, plate, and round tube from OnlineMetals.com And finally, the Makita Impact Driver, Dual 5 Ah batteries, and Makita dual-port charging pad will have to be purchased from Home Depot.

**Manufacturing issues**

Many manufacturing issues have come to the attention of the pruner team as we have moved forward. During the second meeting with the customer for our fall quarter manufacturing meeting, it was determined that the current pruner design was entirely impractical and heavy. The customer set the pruner team on a redesign track. This is problematic for the manufacturing process because it has placed an intense time constraint on the project. However, with the manufacturing process being completed a little each week, it should be able to be finished by the end of winter quarter.

After the weight problem was addressed with a first round of re-designing, the problem of required linear force was addressed by optimizing the cutting system of the pruner in order to achieve the maximum mechanical advantage necessary during the maximum branch cut.

However, after the pruner had been optimized for mechanical advantage the H.F. Hauff sales department determined that the look of the optimized pruner was not very marketable. This resulted in another round of redesigning where the team has been dialing back the mechanical optimization in order to achieve a more consumer friendly look to the product.

Another manufacturing issue for the pruner team has been delivery times for necessary components. Many required components for the manufacturing process are taking much longer to arrive than we had previously thought they would. This has been an issue because many measurements and technical aspects of these components need to be researched in order to move the manufacturing process forward.
Testing Method

Introduction
The Power system of the pruner must be tested thoroughly to ensure that the customer, Mr. Maniadakis, is satisfied with performance and design. The testing of the power system will be focused around two factors; the system’s ability to cut a 1.5” branch (maximum branch cutting), and the system’s ability to cut at a rate of 250 1 inch diameter branches per hour without exceeding an operating temperature of 110° F (endurance branch cutting). However, this maximum operating temperature which was established in the requirements for the power system has changed as the design process has moved forward. The housing department (Erich Heilman) has made a design decision to have the motor of the linear actuator be placed behind the operator’s hand. This placement of the actuator is different from the system found in the Treelion where the actuator was positioned directly under the operator’s hand. The excessive heat caused Mr. Maniadakis discomfort and was a primary problem with the Treelion design. Since the 110° F operating temperature was established for the comfort of the user, it may be acceptable for the linear actuator to exceed the maximum temperature due to the position of the actuator motor in the new design.

Method/Approach

The testing of the pruner power system is focused around two aspects of power system performance; maximum branch diameter cutting and endurance branch cutting. The materials which will be needed are listed below;

Testing Materials:
1. Thermocouple
2. Stopwatch
3. Spreadsheet Software (Microsoft Excel)

Both of the tests which will be performed for the pruner power system can be performed in the senior project room of Hogue Technology building at Central Washington University.

Testing Procedures

1. Maximum Branch Cutting:
   To ensure the power system is able to transmit enough power to the cutting system of the pruner to cut the 1.5” maximum branch diameter, a test must be performed. For this test, branch samples will be used which have an approximate diameter of 1.50”. Since the pruner is expected to be used in an orchard environment, the test samples will include 5 apple branches (wet and dry) and 5 cherry branches (wet and dry). The test branches will also include 1 spruce branch and 1 other evergreen branch for test sample variety.
   During the maximum branch test cuts, the cycle time of a cut when cutting the maximum branch size will be measured, using a stopwatch. It is expected that the cycle time of a cut will increase when cutting a maximum size branch. However, the cycle time of the cut must be no longer than the required 2.0 seconds. The temperature of the power system when cutting maximum diameter branches will also be measured using a thermocouple.

2. Endurance Branch Cutting:
To ensure that the power system of the pruner can remain under 110° F when cutting at a rate of 250 1” diameter branches/ hour, a test must be performed. It is impractical to attempt to obtain 250 green (wet) branches for the sake of testing the power system temperature. However it is practical to obtain 25 green branches for the testing process. A thermocouple will be attached to the actuator of the power system to record how the temperature of the system changes when consecutively cutting 25 1 inch branches of the different varieties (apple, cherry, and spruce). The data from this test can be analyzed using Microsoft Excel. A predictive plot can be made from test data to determine what the power system temperature would be after 250 consecutive cuts.

**Deliverables:**

The testing of pruner power system will take place during the first week of spring quarter 2016. This testing will follow the construction of the pruner prototype. The following weeks of spring quarter will be allotted for the testing of the other divisions of the pruner projects, housing and ergonomics, and the cutting system. The test data for all sections will be documented in the Appendix.

**Budget/Schedule/Project Management**

**Proposed Budget**

In the design requirements for the pruner power system, it is established that the total cost of all components and construction should be no more than $700. A summarized table of the quantity and cost of all pruner system components can be found in Appendix C1. It can be seen in the appendix that the power system components actually cost $162 less than the previously proposed budget for the power system. This is mainly due to the selection of a new drive system, Makita, which has been a better choice in every single, including cost. Although the redesign process has placed a major time constraint on the pruner team, it has spurred further optimization and practicality for the pruner design.

**Proposed Schedule**

A high level Gantt chart which establishes the proposed schedule of the pruner project is included in Appendix E1. The primary milestones included in the chart are listed below:

1. Fall Quarter Proposal Finished – 12/9/15
2. Proposal Revisions – 12/18/15
3. Prototype Construction Complete – 3/15/15

The project should take 223 hours in total. This total is calculated from the Gantt chart displayed in the Appendix K1.
Project Management

Human Resources:
- The construction of the pruner power system relies heavily on the cooperation of the Hogue Technology Building’s lab technician, Matt Burvee. Mr. Burvee’s assistance and expertise in the machine shop is extremely valuable to the progress of construction. The cooperation of our team with Mr. Burvee will ensure that we have frequent access to the machine shop and will be prioritized above other groups with regards to effort.

- Professors Greg Lyman and Christopher Hobbs are crucial resources for the construction of the circuit which will be required for the cutting cycle to operate correctly. They will consult the power system division of the pruner team to ensure that appropriate circuit components are purchased for the pruner trigger circuit.

- Professor Johnson is a crucial resource for assistance with stress and failure analysis. His expertise will help ensure the pruner team does not overlook any aspects of design, with regard to strength and stress analysis.

- Professor Pringle is another important resource for information and guidance with design decisions and analysis. Professor Pringle’s expertise will help the pruner team in the production of a successful product.

Physical Resources:
- The machine shop of Hogue Technology Building
- The materials lab of Hogue Technology Building
- The Construction Management Testing Lab
- The foundry of Hogue Technology Building

Software Resources:
- Multisim circuit builder
- Dassault Solidworks
- Microsoft Excel

Financial Resource:
- Neil Hauff, president of H.F. Hauff Co. Inc.: Neil is willing to pay for justified design decisions and components. At the beginning of winter quarter, the pruner team will meet with Neil Hauff to discuss what components will require funding. Design decisions will be justified to Mr. Hauff through specification sheets, empirical testing data, and analysis performed by the pruner team.

Discussion

Design Evolution/Performance Creep
As the design process moves into the prototype construction phase, aspects of the original proposed design may have to be changed to accommodate unforeseen factors. As the process moves forward, the design changes and evolution will be recorded.

Many aspects of the original design finalized at the end of fall quarter have been changed. A few changed are listed below:

1. Instead of purchasing a linear actuator, the team is now using a Makita impact driver as the primary source of torque for a custom-made actuator.
2. Instead of using the Pellenc battery back which was used for the Treelion, the pruner team will now utilize the dual-port charging pad for the Makita LXT series. This pad will be converted into a mobile battery pack with two 5 Ah Makita batteries hooked together in parallel.
3. Instead of having the main driver be at the far end the Makita is now located in the approximate middle of the pruner and a “double-pistol grip” handle system will now be used as per request of the financier.

Project Risk Analysis

One risk involved with the current design process is the potential for the final design to not be easily mass-produced. The KV21 linear actuator may not easily purchased in mass quantities for a decent price and it may not be feasible when the pruner design goes to production level.

Another risk of the current pruner design is the possibility that a battery system may have to be purchased/produced. The battery system to be used in the current design is the Treelion 44VDC battery belt design by Pellenc, the parent company of Treelion. A new battery system may result in changes in design due to supply voltage, battery weight, battery life of the different battery system.

Successful

If the prototype of the pruner proves to be a successful design, with regard to design requirements, testing results, and success criteria, the design may be acknowledged by Neil Hauff to be a product to be mass-produced. In this next phase of design, the ascetics and features of the pruner design would be improved and re-designed.

Next Phase

The next phase of the design process is to construct a working prototype of the pruner power system. After the power system is manufactured, it will then be assembled with the cutting system components and the housing components constructed by the other members of the pruner design team.

Conclusion
The problems with the original Treelion pruner used by Emmanuel Maniadakis can be summarized in the list below:

- The device is too hot to hold on to.
- The trigger system is uncomfortable.
- The “hold trigger to keep cutting” feature of the Treelion is not comfortable or practical.
- It’s not long enough.

The new design of the Hauff pruner will solve these problems involved with pruner use and performance summarized in the list below:

- The pruner actuator/motor and surrounding housing will not exceed a temperature of 110°F after cutting a maximum branch size of 1.50 in. or cutting 250 1 in. diameter branches/hour for 1 hour.
- The “single-finger” trigger system that was not comfortable for the user before is replaced with a 4-finger hand trigger in the new design.
- The trigger system will now require only a momentary pull which initiates the cutting cycle of the pruner.
- The pruner design will have a length of 36 in. from the top of the trigger to end of the blade.
Appendix A – Analyses

A1: Design Concept

A2: Trigger Concept
A3: Trigger Circuit Drawing

A4: Duty Cycle Calculation

Duty Cycle of Cutting Force Device

Given: Cutting Force device
Cut cycle time = 2.0s = t₁
Time between cycles = 8.0s = t₂

Find:
Duty Cycle: D

Solution:
\[ D = \left( \frac{t₁}{(t₁+t₂)} \right) \times 100 = \left( \frac{2.0}{(2.0+8.0)} \right) \times 100 \]

\[ \Rightarrow D = 20\% \]

Therefore, a duty cycle of no greater than 20% is required for cutting force device.
A5: Mechanical Power Output

Given: Cutting force device:
Cutting cycle time, \( T_c = 2.0 \) s
Source voltage, \( V_s = 440 \) V
Stroke length (one way), \( L = 2 \) in
Force required for cut, \( F_c = 450 \) lb

Find: Mechanical power output of cutting force device, \( P_0 \) (W)

b) Resulting Current Solution:
First, linear velocity of stroke:
\[ V = \frac{2 \text{ in}}{2 \text{ s}} = 1 \text{ in/s} \]

a) Power output:
\[ P_0 = F_c \cdot V \]
\[ = 450 \text{ lb \cdot in/s} \cdot 1 \text{ in/s} = 450 \text{ lb \cdot in} \]

\[ P_0 = 450 \text{ lb \cdot in} \cdot \left( \frac{1 \text{ ft} \cdot \text{in}}{12 \text{ in}} \right) \cdot \left( \frac{1 \text{ HP}}{550 \text{ ft} \cdot \text{in}} \right) \cdot \left( \frac{746 \text{ W}}{1 \text{ HP}} \right) \]

\[ \Rightarrow P_0 = 50.7 \text{ W} \]
A7: Cutting Test Data (Testing Round #1)
The graphs displayed below show the force required during the cut of various sizes of plum branches.
(1.75” diameter branch #1)

(1.75” diameter branch #2)

(1.75” diameter branch #3)
(1.25” diameter branch)

(1.8” diameter branch)
A8: Tree Branch Testing (Round #2) Testing Apparatus
A9: Tree Branch Testing (Round #2) Data
(Test #1 - Cherry – 1.50 in Diameter)

(Test #2 – Cherry – 1.34 in Diameter)

(Test 3 – Cherry – 1.52 in Diameter)
(Test 4 – Dead Apple Branch – 1.30 in. Diameter)

(Test 5 – Spruce – 1.28 in. Diameter)
(Test 6 – Knot-Ridden Cherry – 1.60 in. Diameter)
Thomas Wilson  A10

Timus Olsen downward velocity = 4.5 in/min \cdot \left( \frac{1\text{ in}}{60\text{ s}} \right) = 0.075\text{ in/s} 

Timus Olsen distance where most force is required on 1.50 in Cherry branch = 1.8 in

Time into test when most force required:

\[ \frac{0.075\text{ in}}{1\text{ s}} = \frac{1.8\text{ in}}{t} \implies t = \frac{1.8\text{ in}}{0.075\text{ in/s}} \implies t = 24\text{ s} \]

In test video, 24s into cut the Fiskars is at the following orientation:

Therefore we know most force is required at this orientation and cutting point is approximately 1.50 in from pin.
A11: Average Cutting Point Force Calculation

\[ \sum M = 0: F_A(1.5\text{ in}) - (500\text{ lb})(2.7125\text{ in}) = 0 \]

\[ F_A = \frac{500\text{ lb}(2.7125\text{ in})}{1.5\text{ in}} \rightarrow F_A = 770.83\text{ lb} \]
A12: Actuator Pin Sizing Calculation

1020 Cold Rolled Steel
55 ksi = $s_y$

$S_x = \frac{s_y}{2} = 27.5$ ksi

$S_y = 27.5 \times (0.50)$ ksi

$S_x = 13.75$ ksi $= T_{max}$

$T_{max} = \frac{V}{A} = \frac{V}{\frac{\pi}{4}D^2}$

$\Rightarrow D = \sqrt{\frac{V}{T_{max} \left( \frac{\pi}{4} \right)}}$

$\Rightarrow D > \sqrt{\frac{250}{13.75}}$ (ft)

$\Rightarrow D > 0.152$ in

$\Rightarrow D = \frac{1}{4}$ in
Option 1: Carbon Fiber Driving Rod:
Archwest Composite standard modulus:
$E_{\text{max}} = 700 \text{ ksi}$
$E_{\text{max}_1} = 200 \text{ ksi}$
$E_{\text{max}_2} = 30 \text{ ksi} \Rightarrow E_{\text{max}} = 467 \text{ ksi}$

Option 2: Aluminum Driving Rod:
AISI 6061
$E_{\text{max}} = 8 \text{ ksi}$
$E_{\text{max}_2} = 8 \text{ ksi} \Rightarrow E_{\text{max}} = 4 \text{ ksi}$

$$d = \frac{D^2 - 4F}{\pi a^2}$$

Option 1: AISI 6061
$$d = \sqrt{\frac{0.75 \text{ in}^2 - \frac{4(600 \text{ lb})}{4E_1 \text{ ksi} \text{ in}^2 \cdot \pi}}}{a \pi}$$
$\Rightarrow d = 0.610 \text{ in} \Rightarrow \text{Area} = 0.29 \text{ in}^2$

Therefore, thickness $t > 0.1405 \text{ in}$
Tube to use: "Onlinemetals" price: $47.96$

$\text{weight} = \rho \cdot \text{Vol}$
$= 0.0975 \frac{\text{lb}}{\text{in}^3} \cdot (0.29 \text{ in}^2 \cdot 0.24 \text{ in})$

Option 2: Carbon Fiber
$$d = \sqrt{\frac{0.75 \text{ in}^2 - \frac{4(600 \text{ lb})}{700E3 \text{ ksi} \text{ in}^2 \cdot \pi}}}{a \pi}$$
$\Rightarrow d = 0.250 \text{ in}$

$\Rightarrow t_{1} > 0.0073 \text{ in} \Rightarrow \rho = 0.0578 \frac{\text{lb}}{\text{in}^3}$

$\text{weight} = \rho \cdot \text{Vol} = (0.0578 \frac{\text{lb}}{\text{in}^3})(0.29 \text{ in}^2 \cdot 0.24 \text{ in})$

$\Rightarrow \text{weight} = 0.402 \text{ lb}$

Summary

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A14: Carbon Fiber Driving Rod Tension Sizing

Driving Rod - Tensile Strength Sizing

** GIVEN **
- Driving Rod: \( D = 0.75 \text{ in} \)
- Material - Carbon Fiber
- Clearwater Composites
- \( S_y = 200 \text{ ksi} \)
- \( P = 600 \text{ lb} \)

** FIND:**
- Minimum \( T \) for driving rod

** SOLN:**
- \( \sigma_{\text{allow}} = \frac{S_y}{2} = \frac{200 \text{ ksi}}{2} = 100 \text{ ksi} \)
- \( A = \frac{\pi}{4} (D^2 - d^2) \)
- \( \sigma_{\text{allow}} = \frac{P}{A} = \frac{P}{\frac{\pi}{4} (D^2 - d^2)} \)
- \( (D^2 - d^2) = \frac{P}{\sigma_{\text{allow}} (\frac{\pi}{4})} \)
- \( d = \sqrt{D^2 - \frac{P}{\sigma_{\text{allow}} (\frac{\pi}{4})}} \)

\( \Rightarrow d = \sqrt{0.75^2 - \frac{600 \text{ lb}}{100 \text{ ksi} (\frac{\pi}{4})}} \)

\( \Rightarrow d = 0.74 \text{ in} \)

Therefore \( T > 0.01 \text{ in} \)
Given:
Driving rod collars
Dimensions in Figure 1

Find:
Will SAE 1020 cold-drawn appropriate material?
Design factor =
\( S_f = 51 \text{ksi} \Rightarrow S_{\text{actual}} = \frac{51 \text{ ksi}}{1.25} \)
\( \Rightarrow S_{\text{actual}} = 40.8 \text{ ksi} \)
Stress concentration factor from efatigue.com, \( 1.94 = K_f \)
Blade end collar will have greatest stress due to smaller cross-sectional area at fillet.

Max stress @ fillet:
\[ \sigma_{\text{max}} = K_f \frac{F}{A} \]
\[ = 1.94 \left( \frac{60016}{6.8 \sin(0.1300)} \right) \]
\( \Rightarrow \sigma_{\text{max}} = 11.19 \text{ ksi} \)

\( \sigma_{\text{max}}(11.19 \text{ ksi}) < S_{\text{actual}}(40.8 \text{ ksi}) \)
Therefore, fillet radius and material is acceptable.
SAE 1020 cold-drawn is cheap and available.
A16: Driving Rod Linkage Width Sizing

Given Driving Rod linkage dimensions (Figure 1)
- Safety Factor: $N = 2$
- Material: SAE 1020
- Load: $P = 2$

**REQUIRED:**
- Minimum width of linkage

**SOLUTION:**
- Yield of SAE 1020 Cold drawn:
  - $S_y = 51$ ksi (MOTT)
  - $S_y = \frac{S_y}{N} = \frac{51}{2} = 25.5$ ksi

  Area: $A = (w \cdot 0.138^\circ) - (0.25 \cdot 0.138^\circ)

  $A = 0.138^\circ (w - 0.25)$

  $\sigma_{max} = \frac{F}{A} = \frac{F}{0.138^\circ (w - 0.25)}$

  $w = \left[ \frac{F}{\sigma_{max} \cdot 0.138^\circ} \right] - 0.25in

  $w = \left[ \frac{600lb}{25E3 lb/in^2 \cdot 0.138^\circ} \right] - 0.25in

  $w = 0.738in$

Therefore, a width of $\frac{3}{4}''$ is acceptable for the linkage width.
Driving Rod - Buckling Analysis

**GIVEN**

Driving Rod in Figure 1 experiences max. actuator load of 600 lb when trying to open blade but can’t (Compression)

**REQUIRED**

Will tube buckle under max load

**SOLN**

Using Mott’s design system for buckling columns:

Radius of Gyration:

\[ r = \sqrt{I/A} = \sqrt{\frac{0.015 \text{ in}^4}{0.245 \text{ in}^2}} = 0.247 \text{ in} \]

Slender Ratio:

\[ S.R. = \frac{K L}{r} = \frac{1.0 \times 30 \text{ in}}{0.247 \text{ in}} = 121.4 \]

Column constant:

\[ C_c = \sqrt{\frac{2 E I}{S_Y}} = \sqrt{\frac{2 \times 30 \times 10^6 \text{ psi}}{200 \times 10^3 \text{ psi} \times \frac{1}{4} \text{ in}^2}} = 54.4 \]

\[ \Rightarrow C_c > S.R. \Rightarrow \text{LONG COLUMN} \]

Critical load:

\[ P_c = \frac{\pi^2 EA}{(K L / r)^2} \]

\[ \Rightarrow P_c = \frac{\pi^2 (30 \times 10^6 \text{ lb/in}^2)(0.245 \text{ in}^2)}{(121.4 \text{ in})^2} = 4.922 \text{ lb} \]

Allowable load:

\[ P_a = \frac{P_c}{2} = \frac{4.922 \text{ lb}}{2} = 2.461 \text{ lb} \]

\[ \Rightarrow P_a = 2.461 \text{ lb} > 600 \text{ lb} \]

Therefore, tube dimensions established for tension of rod allow for an acceptable buckling load.

Rod will not buckle under max. compression.
A18: Cutting Point Force Calculation

Given: A rod pulls with 600 lb on a linkage pair attached to a pivoting blade. The blade reacts on the branch at P. The angle configuration shown in the figure is where the rod force is required when cutting the branch. The x-axis is fixed and the rod only moves on an x-axis.

Find: Force applied to branch

Solve: Force applied to branch (F)

\[ F = 634 \text{ lb} \]
A19: Shear Pin Sizing for Cutting System Pin

Choose AISI 1018 steel and design to yield strength (σ_y = 41 ksi).

Choose a length of 0.625 in.

FBD - One Linkage

\[ F = \left( \frac{1.5}{287 \text{ lb}} \right) \]

Choose a standard thickness of 0.125 in. for the linkages. Consider using a cheaper material with a lower yield strength.

Pin Dimensions

Choose Clevis Pin
Choose AISI 1018 steel and design to yield strength (σ_y = 41 ksi).

Use a Safety Factor of 1.5

Pin A (Double Shear)

\[ I = \frac{d^4}{32} \]

\[ F = (1.5)(287 \text{ lb}) \]

\[ d = \frac{2F}{\pi \sigma_y} \]

\[ A = \frac{2F}{\pi \sigma_y} \]

\[ d = \frac{2F}{\pi \sigma_y} \]

\[ L = 0.1057 \text{ in} \]

Assume thicknesses of rod connection and blade are 0.15 in.

\[ L = 2(0.125) + (0.15 \text{ in}) \]

\[ L = 0.40 \text{ in} \]

For both pin A and B, use a standard diameter of 0.25 in. and a usable length of 0.40 in. Consider using a cheaper material.
Appendix B – Power System Drawings

B1: Drawing A1 – Power System Assembly

B2: Drawing A2: Ball Screw Assembly
B3: Drawing A3: Ball Nut Assembly
B4: Drawing A4: Makita Dual-Port Charger
B5: Drawing A5: Makita XDT08 Model
B6: Drawing A6: 5/8" Ball Screw
B7: Drawing A7: Thrust Plate

H.F. Hauff Co. Inc.

Thrust Plate

<table>
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<th>Sheet</th>
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<tr>
<td>A</td>
<td>A7</td>
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# B8: Drawing A8: Thrust Bearing

**Thrust Bearing**

---

**Dimensions**

- \( \phi 0.73 \)
- \( \phi 502 \)
- \( \phi 936 \)

---

**H.F. Hauff Co. Inc.**

**Thrust Bearing**

---

**PARTS DIMENSIONS**

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**SPECS**

- \( \text{SPEC} \)
- \( \text{REV} \)
- \( \text{DATE} \)
- \( \text{VTG} \)
- \( \text{M/T} \)

---

**Notes**

- Specification
  - [Details]
  - [Details]

---

**Control**

- [Control Number]
- [Control Date]

---

**Reference**

- [Reference]
- [Reference]

---

**Drawn By**

- [Name]
- [Date]

---

**Approved By**

- [Name]
- [Date]

---

**Printed By**

- [Name]
- [Date]
B9: Drawing A9: Hex Adapter

SECTION A-A

SECTION B-B

NOTE: 1/4" RADIUS AT BASE OF HEX ARE MADE BY A 1/2" END MILL.
B10: Drawing A10: Ball Nut
B11: Drawing A11: Weld Plate

Aluminum Weld Plate

H.F. Hauff Co. Inc.

Scale 1:1

Sheet 1 of 1
B13: Drawing A13: Linkage Pin Connector
Appendix C – Parts List

C1: Parts and Price List

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<tr>
<td>Nickel Titanium</td>
<td>0.160” x 2.50”</td>
<td>NDC</td>
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<td>Online Metals</td>
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<td>Grooved Clevis Pin with Retaining Ring</td>
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<td>McMaster-Carr</td>
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<td>Housing &amp; Erg.</td>
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<td>Carbon Fiber Filament wound tube</td>
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<td>Rock West Composites</td>
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<td>Light Duty Dry-Running Sleeve Bearings</td>
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Power & Trans.

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Appendix D – Budget

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<td>Total Cost of Power System Components</td>
<td>$538</td>
<td></td>
<td></td>
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<tr>
<td>Total Budget For Power Syst</td>
<td>$700</td>
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<tr>
<td>Amount Under Budget</td>
<td>$162</td>
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</tbody>
</table>
Appendix E - Schedule

**E1: Gantt chart: Project Schedule**

**H.F. Hauff Pruner**

### Project Schedule

<table>
<thead>
<tr>
<th>Task #</th>
<th>Description</th>
<th>Start Date</th>
<th>Duration</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Fall Quarter Proposal Finished</td>
<td>2/8</td>
<td>2</td>
<td>x</td>
</tr>
<tr>
<td>2.</td>
<td>Meeting with Hal Hauff [2/8]</td>
<td>3/7</td>
<td>1</td>
<td>x</td>
</tr>
<tr>
<td>3.</td>
<td>Timeline Proposal Examined</td>
<td>10/5</td>
<td>5</td>
<td>x</td>
</tr>
<tr>
<td>4.</td>
<td>Blade Design Research</td>
<td>10/8</td>
<td>8</td>
<td>x</td>
</tr>
<tr>
<td>5.</td>
<td>Power System Research</td>
<td>10/8</td>
<td>8</td>
<td>x</td>
</tr>
<tr>
<td>6.</td>
<td>Housing/Economics Research</td>
<td>10/5</td>
<td>5</td>
<td>x</td>
</tr>
<tr>
<td>7.</td>
<td>Blade System Drawings</td>
<td>5/6</td>
<td>6</td>
<td>x</td>
</tr>
<tr>
<td>8.</td>
<td>Power System Drawings</td>
<td>5/5</td>
<td>5</td>
<td>x</td>
</tr>
<tr>
<td>9.</td>
<td>Molding/Bodywork Drawings</td>
<td>4/4</td>
<td>4</td>
<td>x</td>
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<tr>
<td>10.</td>
<td>Cutting Force Testing</td>
<td>5/3</td>
<td>3</td>
<td>x</td>
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<tr>
<td>11.</td>
<td>Blade System Analysis</td>
<td>4/2</td>
<td>2</td>
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<tr>
<td>12.</td>
<td>Power System Circuit Analysis</td>
<td>4/1</td>
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<td>13.</td>
<td>Molding/Bodywork Analysis</td>
<td>3/3</td>
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<td>14.</td>
<td>Classes End</td>
<td>1/3</td>
<td>3</td>
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### Stage 1: Research and Design

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<thead>
<tr>
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<th>Duration</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.</td>
<td>Winter Break</td>
<td>1/20</td>
<td>20</td>
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<tr>
<td>16.</td>
<td>Proposal Revision</td>
<td>3/15</td>
<td>15</td>
<td>x</td>
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<tr>
<td>17.</td>
<td>Drawing Revision</td>
<td>3/30</td>
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### Stage 2: Design

<table>
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<th>Duration</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.</td>
<td>Meeting w/ Hauff &amp; Co.</td>
<td>3/1</td>
<td>1</td>
<td>x</td>
</tr>
<tr>
<td>19.</td>
<td>Meeting w/ Greg Lyman</td>
<td>3/2</td>
<td>2</td>
<td>x</td>
</tr>
<tr>
<td>20.</td>
<td>Blade Linkage Redesign</td>
<td>3/4</td>
<td>4</td>
<td>x</td>
</tr>
<tr>
<td>21.</td>
<td>Re-creating Actuator Choice</td>
<td>3/6</td>
<td>6</td>
<td>x</td>
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<tr>
<td>22.</td>
<td>Designing Rod Components Resigned</td>
<td>3/4</td>
<td>4</td>
<td>x</td>
</tr>
<tr>
<td>23.</td>
<td>Blade Housing Redesign</td>
<td>3/4</td>
<td>4</td>
<td>x</td>
</tr>
<tr>
<td>24.</td>
<td>Actuator Housing Redesign</td>
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### Stage 3: Construction

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<th>Duration</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.</td>
<td>Purchase All Pruner Components and Material</td>
<td>3/3</td>
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<tr>
<td>26.</td>
<td>Purchase Actuator 1/8/16</td>
<td>1/3</td>
<td>0.5</td>
<td>x</td>
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<tr>
<td>27.</td>
<td>Purchase Carbon Fiber Driving Rod - 1/9/16</td>
<td>1/3</td>
<td>0.5</td>
<td>x</td>
</tr>
<tr>
<td>28.</td>
<td>Purchase M and Steel Material - 1/9/16</td>
<td>1/3</td>
<td>0.5</td>
<td>x</td>
</tr>
<tr>
<td>29.</td>
<td>Purchase Power System Hardware - 1/9/16</td>
<td>1/3</td>
<td>0.5</td>
<td>x</td>
</tr>
<tr>
<td>30.</td>
<td>Purchase Blade Material - 1/15/16</td>
<td>1/3</td>
<td>0.5</td>
<td>x</td>
</tr>
<tr>
<td>31.</td>
<td>Purchase Axle Material - 1/15/16</td>
<td>1/3</td>
<td>0.5</td>
<td>x</td>
</tr>
<tr>
<td>32.</td>
<td>Purchase Linkage Material - 1/15/16</td>
<td>1/3</td>
<td>0.5</td>
<td>x</td>
</tr>
<tr>
<td>33.</td>
<td>Purchase Central Housing Tubing - 1/15/16</td>
<td>1/3</td>
<td>0.5</td>
<td>x</td>
</tr>
</tbody>
</table>
Appendix F – Expertise and Resources

Neil Hauff – President, H.F. Hauff Co. Inc.
Dr. Craig Johnson – Central Washington University
Professor Charles Pringle – Central Washington University

Appendix G – Testing Data

This Appendix will contain the testing data following the construction of the prototype.
Appendix H – Evaluation Sheet
This appendix will contain evaluation sheet of pruner.

Appendix I – Testing Report
This appendix will contain the testing report of the pruner prototype.
Appendix J – Resume

THOMAS WILSON
1901 N. Walnut St. #88 • Ellensburg, WA 98926
Phone: (509)-320-3907 • Email: thomasjwilson@gmail.com

Senior level student of Mechanical Engineering Technology seeking internship or career to gain knowledge, experience, and merit in the field.

GPA: 3.0

Key skills and knowledge areas:

- Knowledge of the processes involved in various aspects of Engineering. Strong command of AutoCAD, SolidWorks, and MS Office.
- Excellent shop and safety skills honed from work as a technician and warehouse worker. Able to diagnose and solve problems within a system or a piece of equipment. Knowledge of basic shop and machining tools.
- Strong team collaboration skills. Able to work with team members to achieve goals. Able to effectively communicate in a workplace.

EDUCATION

Central Washington University – Ellensburg, WA
Bachelor of Science in Mechanical Engineering Technology (BSMET), Graduation: June 2016

Centralia Community College – Centralia, WA
Associate of Applied Science in Energy Technology/Power Operations (AAS) Graduation: June 2013

Napavine High School – Napavine, WA
High School Diploma Graduation: June 2011

TECHNICAL SKILLS

- Programs: AutoCAD, MS Office, Rhino, Solidworks
- Machining: Milling machines, lathes, hand saws, grinders, drill presses, shop saws, taps, and micrometers
- Shop: Basic tool knowledge, hand grinders, bolt kits, battery systems, electrical motor systems, water pump systems, electrical vacuum systems, wiring

WORK EXPERIENCE

- Technician: 1/2014 – 1/2015
  Hired by N.W. Scrubbers and Sweepers as a technician to refurbish and service equipment
- Security and Maintenance Officer: 5/2012 – 9/2012
  Hired by Tacoma Power to maintain and patrol the Idylwynd Park Campground
- Forklift Operator: 9/2012 – 1/2015
  Hired by Fred Meyer Distribution Center at forklift operator and shipping specialist. Employee of the Month (November 2012)
- Shift Manager (Fast Food): 8/2010 – 9/2013
  Hired by Jack in the Box restaurant, promoted to shift manager.

Clubs

- Electric Vehicle Club, C.W.U.
  President, Central Washington University
- American Society of Mechanical Engineers (ASME) Club
  Member, Central Washington University
- American Foundry Society (AFS)
  Member, Central Washington University
Appendix K – References


Stress Concentration Factors – Efatigue.com

Appendix L – Acknowledgements

Neil Hauff – Expertise with stress/failure analysis and mechanical design. Neil provided us with the opportunity to gain engineering merit with the pruner project. Neil provides much support through consultation, teaching, and funding.

Dr. Craig Johnson – Expertise with stress and failure analysis

Professor Charles Pringle – Expertise with proposal requirements, design parameters, and failure analysis

Matt Burvee – Assistance with access to Hogue Technology Building machine shop and expertise with manufacturing/testing technology

Professor Greg Lyman – Assistance with purchasing and constructing components for pruner trigger circuit

Professor Christopher Hobbs – Assistance with construction of trigger circuit

Daniel Gibson – Assistance with Dassault Solidworks software and stress/failure analysis

Erich Heilman – Assistance with stress/failure analysis and proposal formatting

Professor Daryl Fuhrman – Assistance with static analysis of load situations

Professor Tedman Bramble – Expertise with machine shop technology